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Discovery of Extensive [O III] Emission Near M31

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ABSTRACT

We report the discovery of a broad, 1.5° long filamentary [O III] emission nebulosity some 1.2° southeast of the M31 nucleus. This nebulosity is not detected in Hα and has no obvious emission counterparts in X-ray, UV, optical, infrared, and radio surveys. To our knowledge, this emission feature has not been previously reported in the literature. We briefly discuss its possible origin.

Keywords: Galaxies: individual (M31) - Galaxies: halo

INTRODUCTION

Optical emission-line sky surveys are especially useful for identifying various types of emission nebulae including H II regions, planetary nebulae (PNe), supernova remnants (SNRs), stellar wind-blown bubbles, and stellar outflows. The majority of such surveys concentrated on detecting Hα emission along the Galactic plane. However, with the advent of affordable yet sensitive large-format CMOS detectors plus high transmission narrow passband filters, amateur astronomers are playing an increasing role in detecting emission-line nebulae, both large and small, and not limited to the Galactic plane.

The [O III] 4959, 5007 Å emission lines are especially important for nebular studies. Here we present wide-field [O III] images of the area around the M31 galaxy using small but fast telescope + camera imaging systems capable of revealing faint and extended emission nebulae.

OBSERVATIONS

Wide-field exposures of M31 using [O III] 5007 Å and Hα emission-line filters plus broadband RGB continuum filters were obtained over 22 nights in August through October 2022 at various dark observing sites in Lorraine, France. These observations employed a 106 mm refractor and a 6248×4176 pixel CMOS camera which provided a $3.48° \times 2.32°$ FOV with scale of $2.04''$ pixel^{-1}. In order to cut down on background light, narrow passband Hα and [O III] filters (30 Å FWHM) were used.

An initial series of 10 minute exposures of M31 were taken over multiple nights totaling 24.6 hr in [O III] (148×600s), 22.5 hr in Hα (135×600s), plus 2.5 hr in each of the RGB filters (30×300s). These images unexpectedly revealed faint [O III] emission about a degree southeast of M31 which seemed to extend past the edge of the image.

In order to rule out filter reflections from bright stars, scattered light from M31 itself, or equipment artifacts, additional images were taken with the same equipment but now centered at a different sky position. A long series of exposures were again obtained totaling 24.2 hr in [O III] (145×600s), 19.5 hr in Hα (117×600s), plus 2 hr (24×300s) in RGB filters. Faint extended [O III] emission nebulosity was again detected near M31.

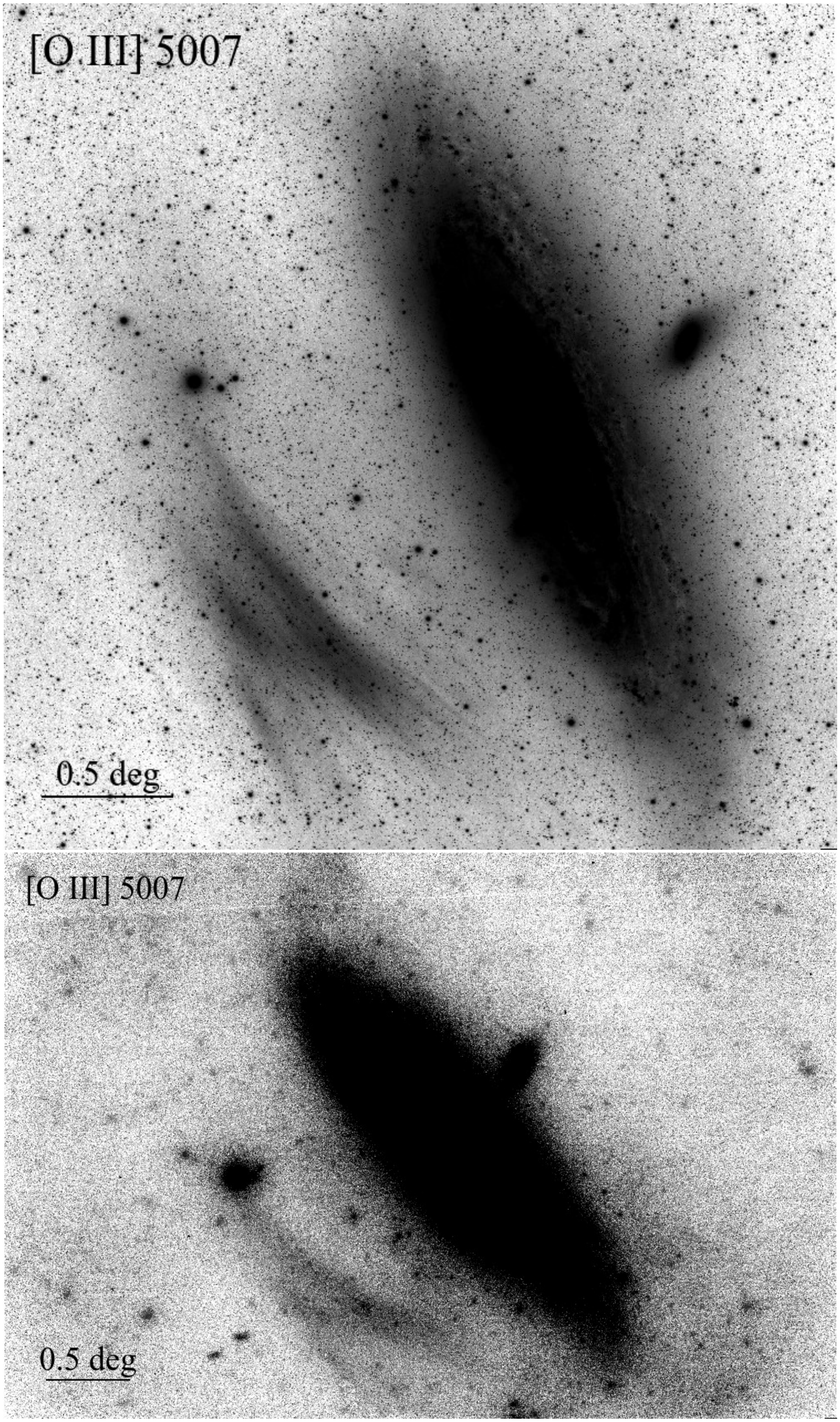

Figure 1. Top: Combined 48.6 hr [O III] 5007 Å exposure image showing the discovery of broad emission nebula southeast of M31. Bottom: Confirming 85.5 hr combined [O III] image. Note: Images are shown as obtained and unrotated. The bright object above the [O III] filaments is the 4.5 mag B5 V star ν And (HD 4727).

Confirming images were sought and successfully obtained in late September through November 2022 using two different telescope + camera systems at an observing site in California. The first series of images totaled 85.5 hr in [O III] (513×600s) and 3.3 hr in RGB filters (40×300s) using a 106 mm telescope and a 9576×6388 pixel camera with a $5.33^\circ \times 3.56^\circ$ FOV. A second series of [O III] exposures totaling 24.9 hr (299×300s) used a 135 mm telescope and a 9576×6388 pixel CMOS camera. Both sets of images confirmed the presence of [O III] emission with the same size and at the same location as seen in the earlier images.

Additional [O III] images were also taken taken in October and November 2022 using different telescopes and cameras located in Lorraine, France and in southern New Mexico, USA. These images confirmed the presence of extensive faint [O III] emission near M31.

RESULTS

Our wide-field imaging of M31 has revealed a faint, 1.5° long [O III] filamentary emission arc[1] roughly 0.45° wide, tilted at position angles of 45° to 55° and centered $\simeq 1.2^\circ$ southeast of M31's nucleus (see Fig. 1). We estimate the brightest portions of the arc to have an [O III] 5007 Å surface brightness of $4 \pm 2 \times 10^{-18}$ erg cm^{-2} s^{-1} arcsec^{-2}. The reality of this nebula is supported by images obtained using five different telescope + camera systems.

To our knowledge, this emission feature has not been previously reported in the literature. We find no appreciable Hα emission coincident with the [O III] filaments, suggesting a flux ratio I([O III])/I(Hα) ≥ 5. We also find no obvious coincident emission in other on-line multi-wavelength image surveys: e.g., X-rays (ROSAT), UV (GALEX), infrared (IRAS/IRIS, Planck), optical (DSS, SDSS), and radio (VLA FIRST, 408 MHz).

Why this [O III] emission feature had not been detected previously is the obvious question to address. Faint [O III] emission nebula like we detected is virtually invisible in broadband filter images. We have considered and rejected the [O III] emission as being an artifact caused by scattered light, internal reflections, image processing, or detector amplifier glow. The absence of an earlier detection appears to be simply due to the combination of an extremely low surface brightness line-emission nebula and its unusually large angular size. Many imaging systems are not suited for detecting such a faint and large line-emission nebulosity.

For example, the CFHT MegaCam [O III] survey of M31's halo PNe population (Bhattacharya et al. 2019) covered the arc's location but did not report any extended [O III] emission. Those images were taken with a relatively wide [O III] 5007 Å filter ($\Delta\lambda = 102$ Å) with a small pixel scale ($0.187''$ pixel^{-1}), inappropriate for detecting faint, diffuse and extended nebulae above background and detector noise. The combination of a wide FOV, pixel scales $\geq 2''$ and narrow interference filters (FWHM ~ 30 Å) has been shown to be especially sensitive for detecting large, low surface brightness nebulosities (Kimeswenger et al. 2021).

DISCUSSION

Curved, filamentary structures like this arc are seen in PNe, and the absence of of IR and UV signals could fit an especially nearby PN scenario. However, CLOUDY models (Ferland et al. 2017) show that high [O III]/Hα ratios with subsolar metal abundances require electron temperatures above 60 000 K, and all potential white dwarfs seen in the region are too cold to generate such a line ratio by photoionization. A filamentary nebula especially bright in [O III] could also be a high-latitude Galactic SNR like G65.3+5.7 (Gull et al. 1977). However, the lack of coincident radio or UV emissions is a problem for a SNR scenario.

The vector of M31's proper motion measured by GAIA points roughly to the [O III] emission arc suggesting a possible interaction of M31 with the Milky Way. But the arc seems much too close to M31 to fit that picture. More likely, it lies within M31's halo and is related to the numerous stellar streams, especially the Giant Stellar Stream whose eastern edge lies close to the [O III] arc (McConnachie et al. 2003; Fardal et al. 2012).

A spectrum of the [O III] emission arc would offer radial velocity information which could establish an association with M31 and its halo. A follow-up spectroscopic study of this emission arc is ongoing.

[1] Strottner-Drechsler-Sainty Object 1; https://planetarynebulae.net

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